Grinder Pump Station Ballast Calculations and Assumptions

Using the Universal Wet Well Without Concrete Anchor

Any buried vessel that is submerged or partially submerged in water will be acted on by an upward buoyant force that attempts to return the vessel to a non-submerged state. The magnitude of this buoyant force is equal to the volume of the vessel that is submerged multiplied by the density of water. To counteract this buoyant force, a suitable ballast is required.

Unique to the E/One models DH071 and WH101 incorporating an injection molded Universal Wet Well, the bottom flange of the tank is designed to capture a suitable column of backfilled soil to resist the upward buoyant force. The weight of the backfill soil along with the soil shear resistance of the soil can retain the DH071 and WH101 tank in the ground – when properly installed in suitable soil conditions.

The amount of ballast force needed is equal to the weight it would take to counterbalance the buoyant force that is exerted on the station.

The total ballast force is a combination of the weight of the soil column acting on the bottom flange of the tank, the weight of the tank, and the soil shear resistance. The ballast force, the force resisting uplift of the station, must be greater than the buoyant force, the force pushing the station up, to have an acceptable installation.

Ballast Forces > Buoyant Force

Step 1: Calculate the Buoyant Force

Buoyant Force = Station Volume x Weight of Water

Example: WH101-92 Grinder Pump Station

- Station Volume: 25.85 cubic feet (known, from table)
- Empty weight of station: 153 pounds (known, from table)
- Weight of Water: 62.4 pounds per cubic foot

Buoyant Force = 25.85 cubic feet x 62.4 pounds per cubic foot = 1613 pounds

Net Buoyant Force = Buoyant Force – Weight of Station (empty)

Net Buoyant Force = 1613 pounds – 153 pounds = ***1,460 lbs***

Step 2: Calculate the Ballast Forces

Ballast Forces = Weight of Annular Soil Column + Soil Shear Resistance

A. Calculate Weight of Annular Soil Column

Weight of Annular Soil Column = Volume of Contributing Soil x Weight of Saturated Soil

Volume of Contributing Soil = (Cylinder of Soil Acting on Base Flange – Volume of Tank)

Example: WH101-92

- Diameter of Universal Wet Well Base (D_{base}): 29.6”
- Nominal exterior diameter of station ($D_{station}$): 25.6”
- Height of Station: 85.6” (burial depth of station)

$$V_{soil} = H \; x \; \pi \; x \left(\frac{D_{base}{}^2}{4} - \frac{D_{station}{}^2}{4}\right)$$

$$V_{soil} = 85.6 \; x \; 3.14 \; x \left(\frac{29.6^2}{4} - \frac{25.6^2}{4}\right)$$

$$V_{soil} = 14{,}844 \; in^3 = 8.59 \; ft^3$$

$$W_{soil} = 8.59 \; ft^3 \; x \; 70 \frac{lbs}{ft^3} = \mathbf{601 \; lbs}$$

B. Calculate Soil Shear Resistance

Soil shear resistance can be simplified and represented as the resistance to movement or friction of soil granules against adjacent granules.

E/One’s soil shear resistance method is adapted from Foundation Analysis and Design (Joseph E. Bowles, 1996). The loading case is *Bearing Capacity of Foundations with Uplift of Tension Forces*.

Simplified Formulas:

For shallow base (tank burial depth, H, is less than the depth of the failure zone, X), H ≤ X :

$$R_{Shear\ Resistance} = s_f \; x \; \pi \; x \; D_1 \; x \; Unit\ Weight_{Soil\_Bouyant} \; x \left(\frac{H^2}{2}\right) x \; K_u \; x \; \tan\varphi$$

For deep base (tank burial depth, H, is greater than the depth of the failure zone, X), H ≥ X :

$$R_{Shear\ Resistance} = s_f \; x \; \pi \; x \; D_1 \; x \; Unit\ Weight_{Soil\_Bouyant} \; x \; (2 \; x \; H - X) \; x \; \frac{X}{2} \; x \; K_u \; x \; \tan\varphi$$

$$Where: \; K_u = K_a = tan^2(45° - \tfrac{\varphi}{2}) \text{ **from text, lateral earth pressure coefficient**}$$

Variables:

- Angle of internal friction between soil (ϕ)
- Shape factor (empirical, lookup from table, s_f)
- Diameter of tank base flange (D_1)
- Height of tank below grade (H)
- Depth of Soil Failure (X)
- Density of Saturated Soil ($UnitWeight_{Soil\_bouyant}$) – 70 lbs/ft³ assumed

	Angle of Internal Friction of Compacted Backfill Soil, ϕ (degrees)						
	20	**25**	**30**	**35**	**40**	**45**	**48**
X/D_1	2.5	3	4	5	7	9	11
s_f	1.12	1.3	1.6	2.25	4.45	5.5	7.6

Soil Shear Resistance Calculation Process:

1. Assume an angle of internal friction
2. Calculate depth of soil failure (X)
3. Determine which Soil Shear Resistance formula to use (deep base or shallow base)
4. Calculate Soil Shear Resistance

Example (WH101-92)

1. Assume an angle of internal friction.
   a. E/One suggests using an angle of 30 degrees for recommended ASTM D2321 Class 1 and Class 2 backfill.
2. Calculate depth of soil failure
   a. From table, 30-degree soil failure correlates to a X/D1 ratio of 4
   b. Therefore:
   $$\frac{X}{D_1} = 4 \ or \ 4 * D_1 = X \ or \ X = 4 * 29.5 = 118 \ inches = 9.83 \ ft$$
3. Determine if "deep base" or "shallow base" condition.
   a. H = 85.6 inches or 7.13 feet, X = 118 inches or 9.83 feet
   b. Since H < X, shallow base condition exists – use appropriate soil shear equation.
4. Calculate Soil Shear Resistance using shallow base equation:

$$R_{Shear\ Resistance} = s_f \ x \ \pi \ x \ D_1 \ x \ Unit\ Weight_{Soil\_Bouyant} \ x \left(\frac{H^2}{2}\right) x \ K_u \ x \ \tan\varphi$$

$$Where: \ K_u = K_a = tan^2(45° - \tfrac{\varphi}{2})$$

$$R_{Shear\ Resistance} = 1.6 \ x \ \pi \ x \ 2.46 \ feet \ x \ 70 \frac{lbs}{ft^3} \ x \left(\frac{7.13^2}{2}\right) x \ 0.33 \ x \ \tan(30°) = \mathbf{4{,}192\ lbs}$$

Buoyance Summary

The ballast forces (the forces resisting uplift of the station) must be greater than the buoyant force (the force pushing the station up) to have an acceptable installation.

(Weight of Soil Column + Soil Shear Resistance) > Net Buoyant Force

From Example:

- *Weight of Soil Column: 601 lbs*
- *Soil Shear Resistance: 4,192 lbs*
- *Net Buoyant Force: 1,460 lbs*

(601 lbs + 4,192 lbs) > 1,460 lbs

*****Disclaimer*****

Ballast assumptions and example calculations are provided for reference only. The E/One Universal Wet Well is capable of installation without a concrete anchor if it is properly installed in accordance with E/One installation instructions, including the utilization of suitable backfill materials (ASTM D2321 Class I or Class II material). For these materials, E/One recommends an angle of internal friction of 30 degrees or greater for use in soil shear resistance calculations. Different materials may necessitate different assumptions and different methods for calculating ballast requirements. The engineer of record is ultimately responsible for designing and dictating the suitable ballast requirements for a particular product, site, or project.

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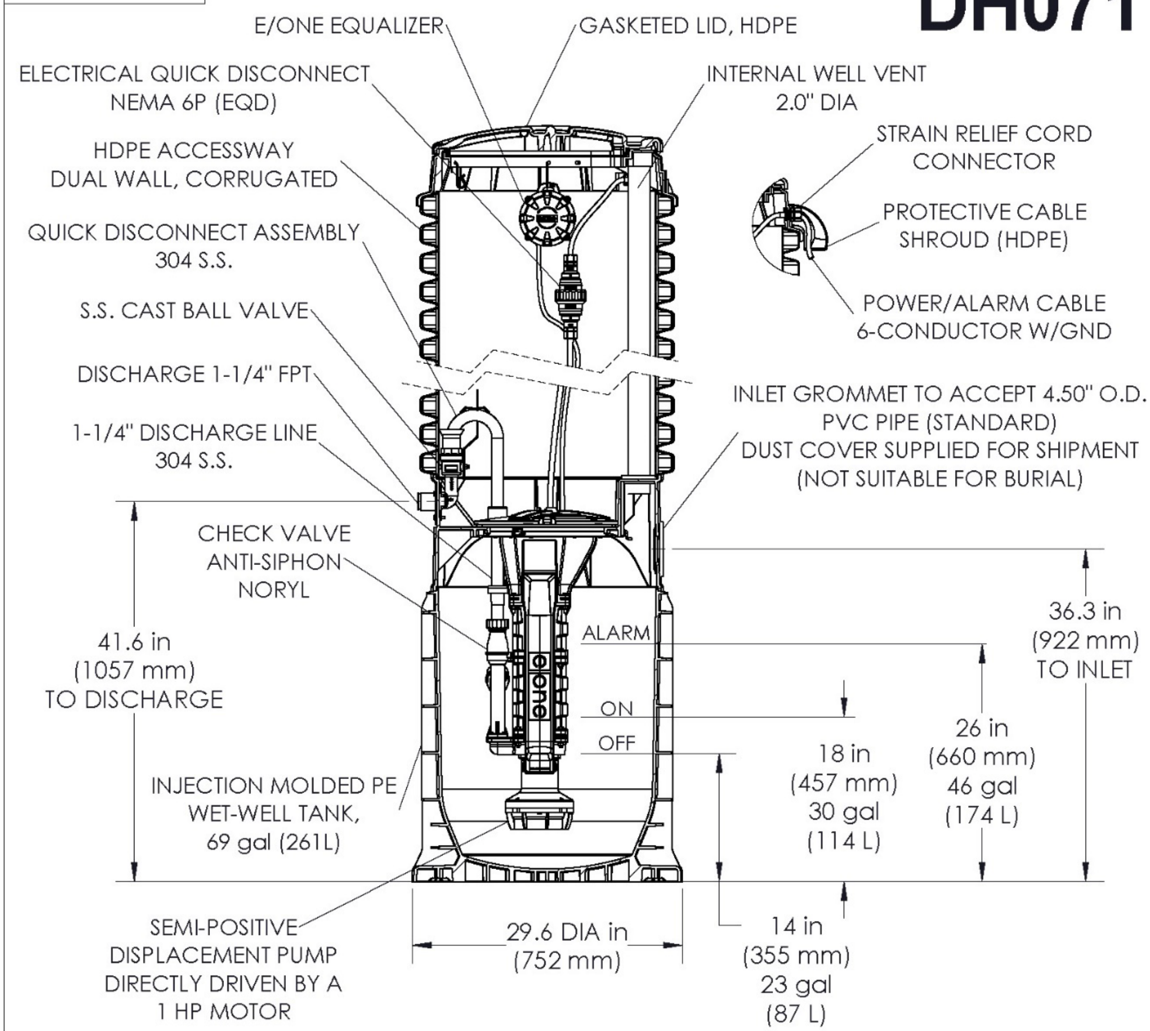
DH071



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CONCRETE BALLAST NOT REQUIRED

NOTE: DIMENSIONS ARE FOR REF ONLY

FIELD JOINT REQUIRED FOR MODELS DH071-129 / DH071-160

SEWER SYSTEMS

MODEL DH071
DETAIL SHEET

NA0050P02

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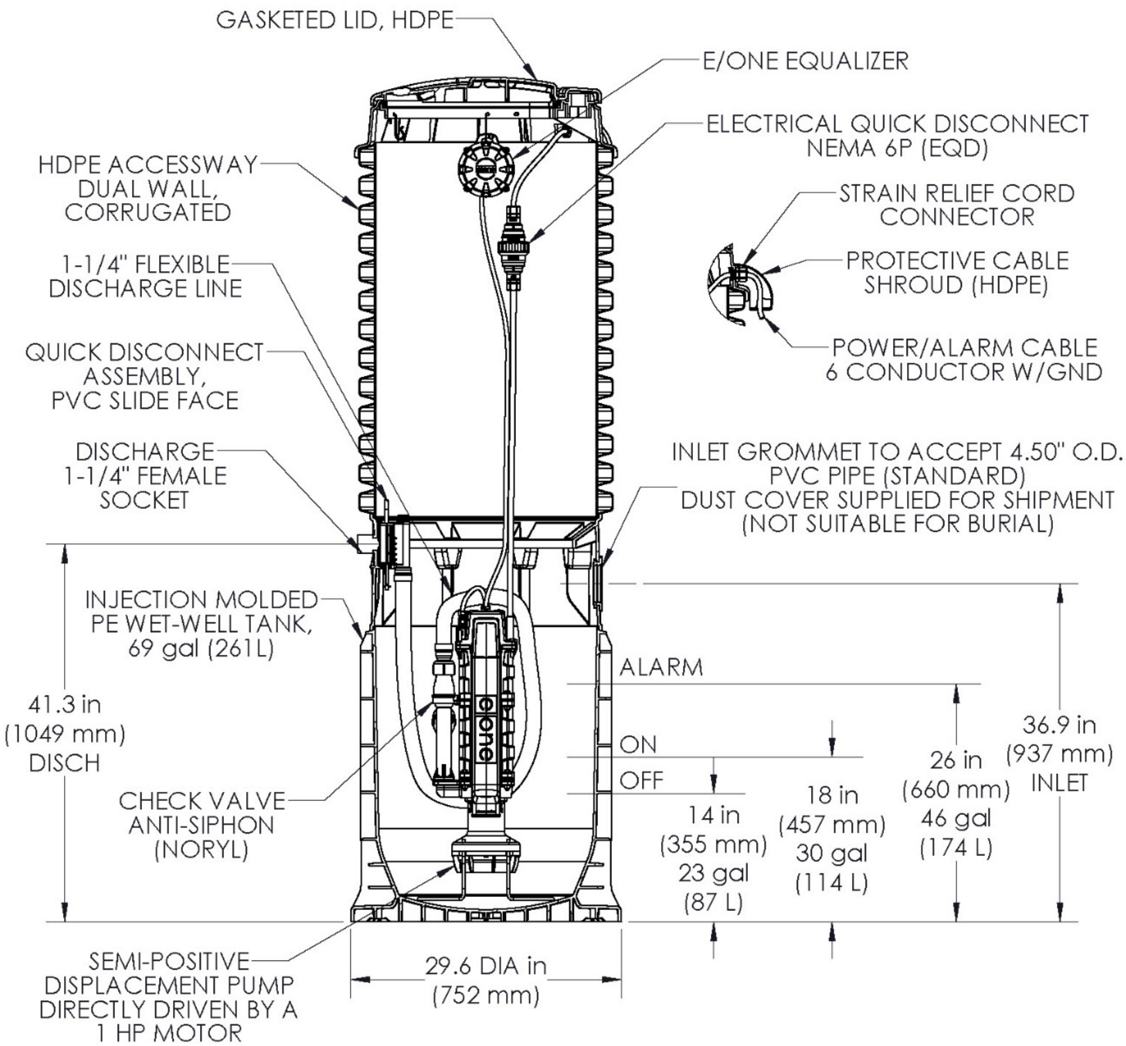
WH101



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CONCRETE BALLAST NOT REQUIRED

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SEWER SYSTEMS

MODEL WH101
DETAIL SHEET

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DH071/WH101 Nominal Weights and Volumes

Station Model *DH071 (WH101)*	**Weight** *lbs (kg)*	**Volume** *ft^3 (m^3)*	**Burial Depth** *ft (m)*
DH071-61 (WH101-60)	120 (54.4)	16.1 (0.456)	4.5 (1.37)
DH071-74 (WH101-74)	129 (58.5)	19.6 (0.555)	5.5 (1.68)
DH071-93 (WH101-92)	153 (69.4)	25.9 (0.733)	7.1 (2.16)
DH071-124 (WH101-124)	178 (80.7)	36.1 (1.022)	9.7 (2.96)
DH071-129 (WH101-130)	191 (86.6)	37.5 (1.062)	10.1 (3.08)
DH071-160 (WH101-159)	221 (100.2)	47.8 (1.353)	12.7 (3.87)

*** Values are nominal and may vary slightly due to minor manufacturing variability. Most common tank configurations are shown. Interpolate as necessary for any intermediate sizes. ***

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